Gravity Waves and Equatorial Waves Observed by HIRDLS

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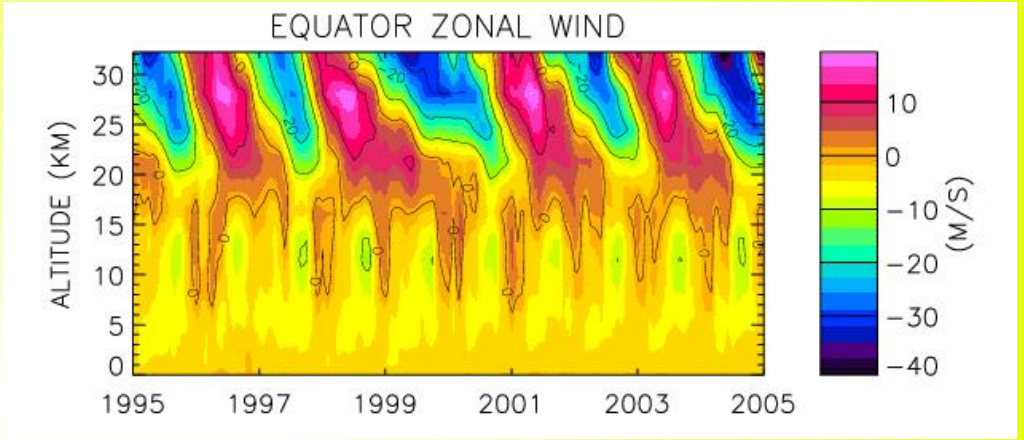
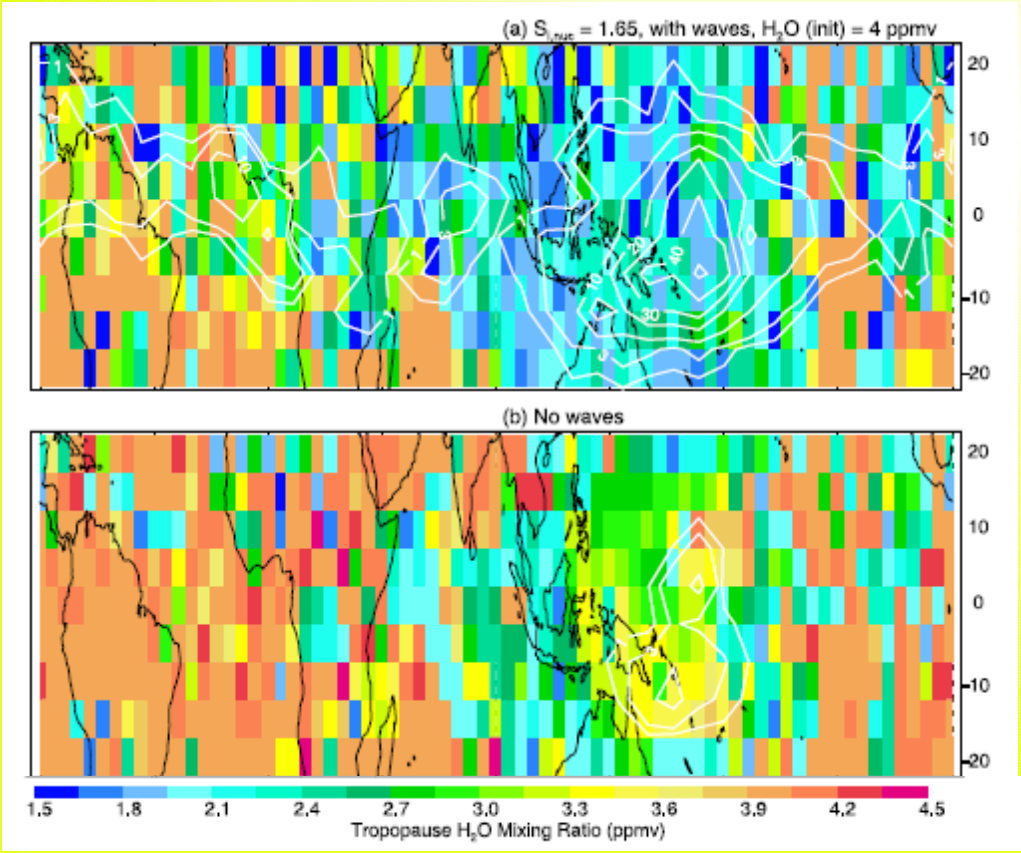
Motivation:

- To validate/improve the treatment of both resolved and parameterized waves in climate and assimilation models.

- In the tropics, these waves drive global circulations (e.g. QBO)





- Tropical waves also affect :

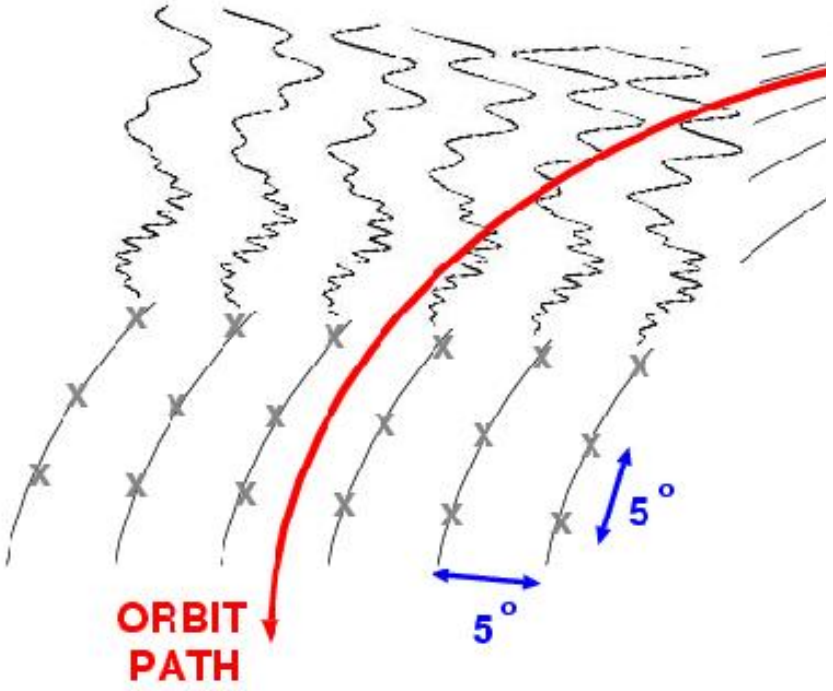
- minimum tropopause temperatures

- cirrus occurrence frequencies

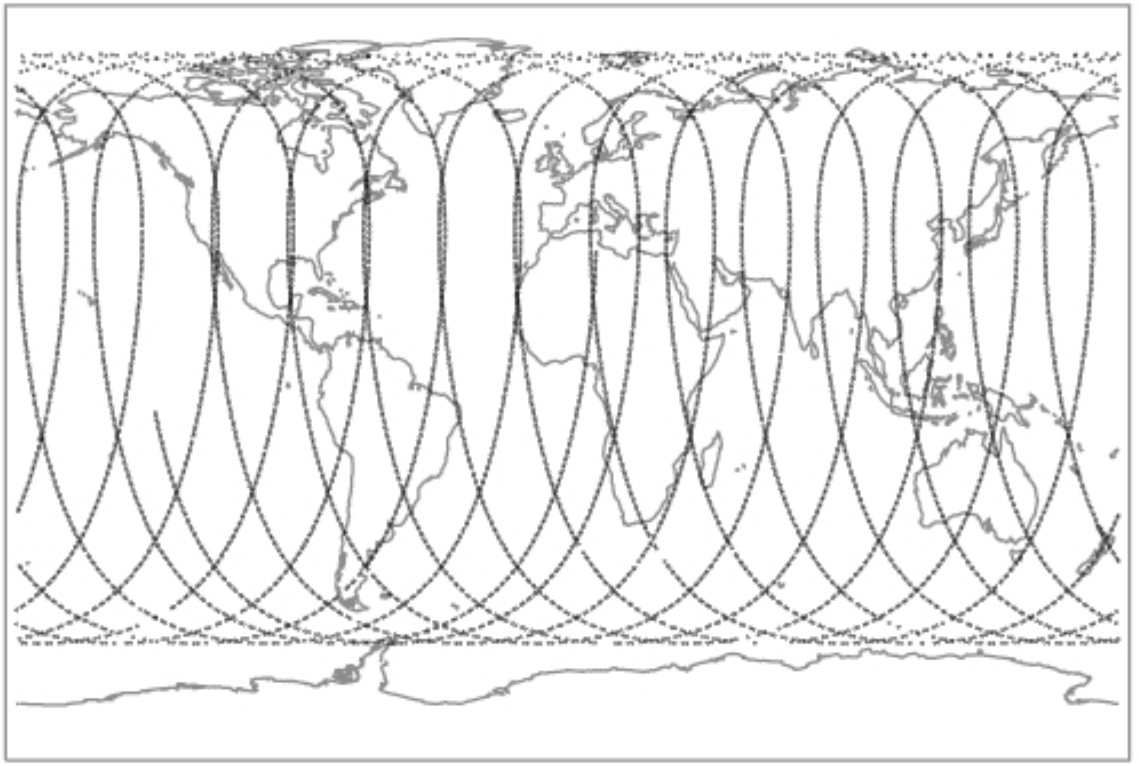
Parcel trajectory results with (top) and without (bottom) including the effects of wave T' [Jensen & Pfister, 2004].

HIRDLS Sampling Patterns

Pre-Launch Planned
Global Mode



Post-Launch Reality:
Traditional (24°) longitudinal sampling
High Resolution (1°) along-track sampling



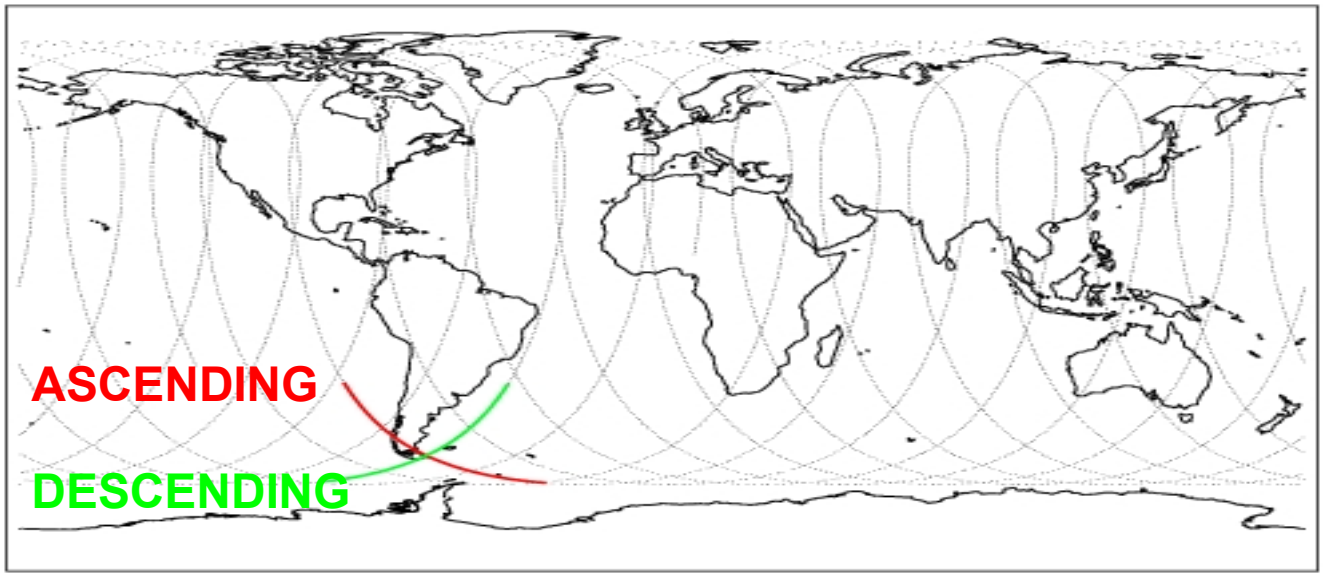
Latitude

Longitude

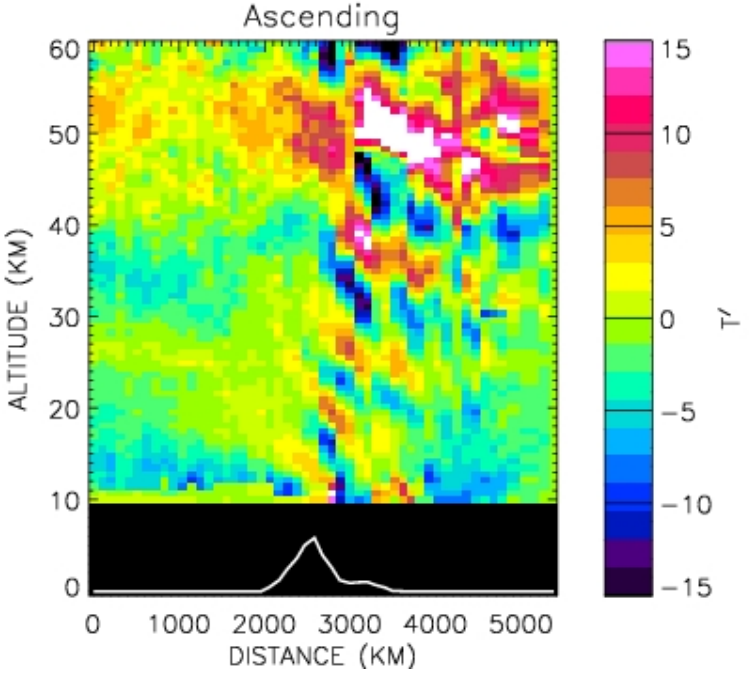
- **Poorer characterization of tropical wave spectrum**
- **Optimal gravity wave observing mode**

HIRDLS

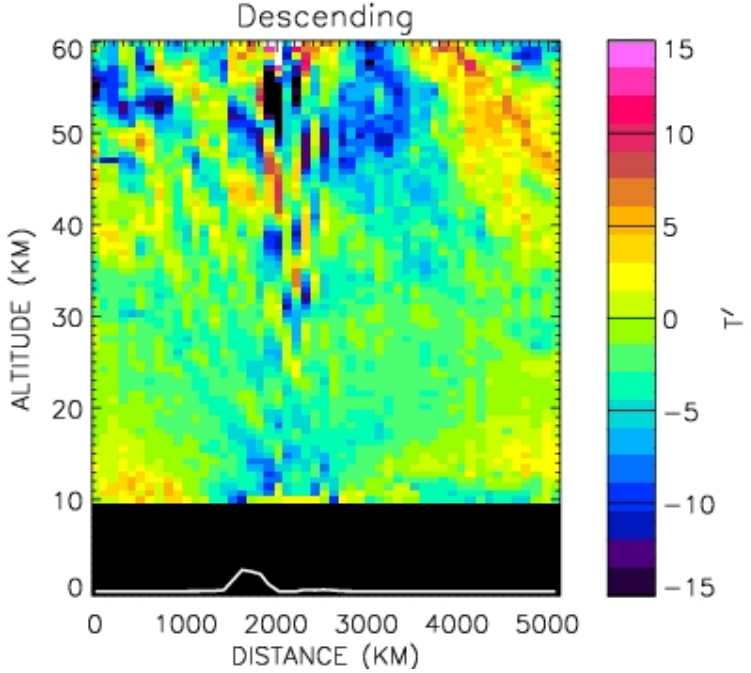
May 8, 2006
Mountain Wave
Events



ASCENDING (red)



DESCENDING (green)



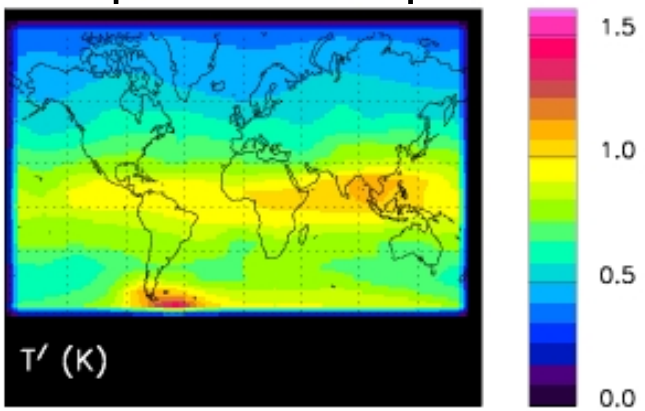
Gravity Waves in HIRDLS

Alexander et al. [2007]

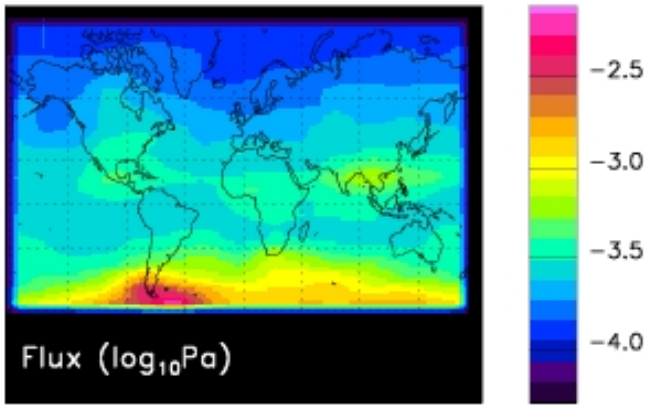
- Allows calculation of Momentum flux ~ $(T')^2 k_H \lambda_Z$

29-day Mean, May 2006

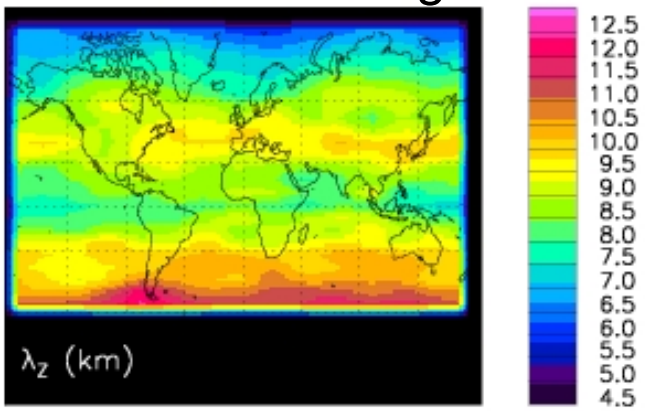
Temperature Amplitude



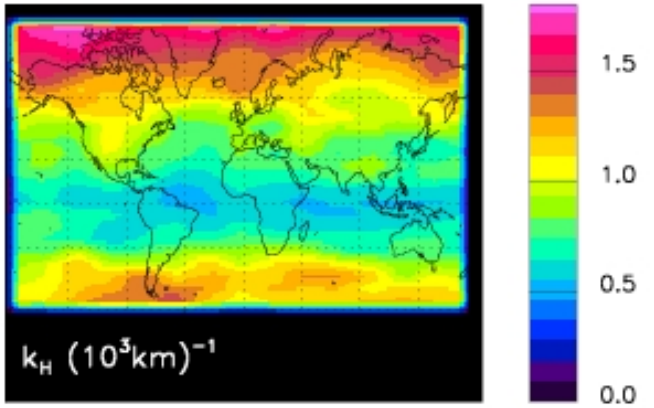
Momentum Flux



Vertical Wavelength



Horizontal Wavenumber



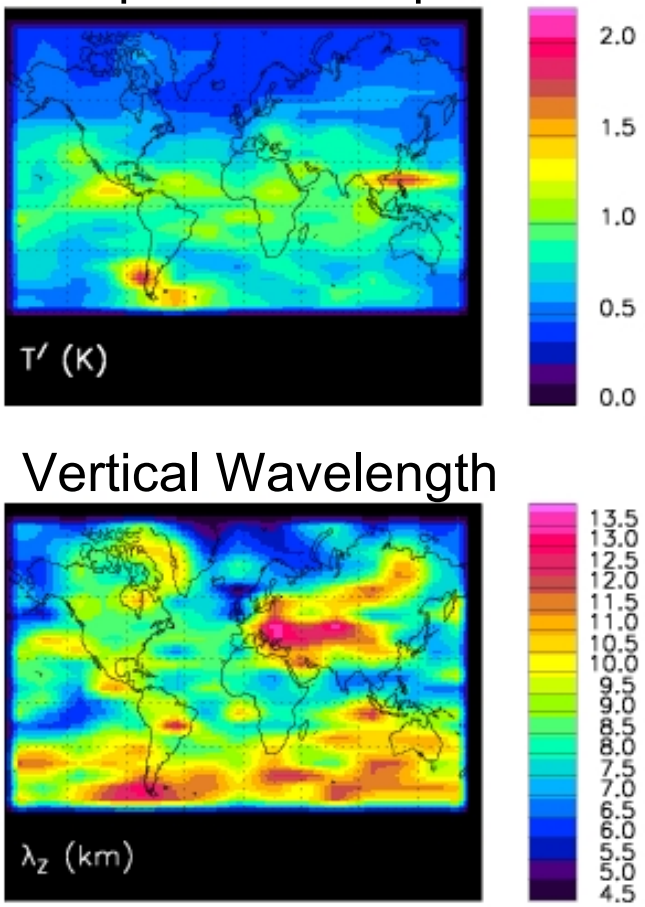
- After removal of zonal wavenumbers = 0-3
- Averaged over z = 20-30 km

Gravity Waves in HIRDLS

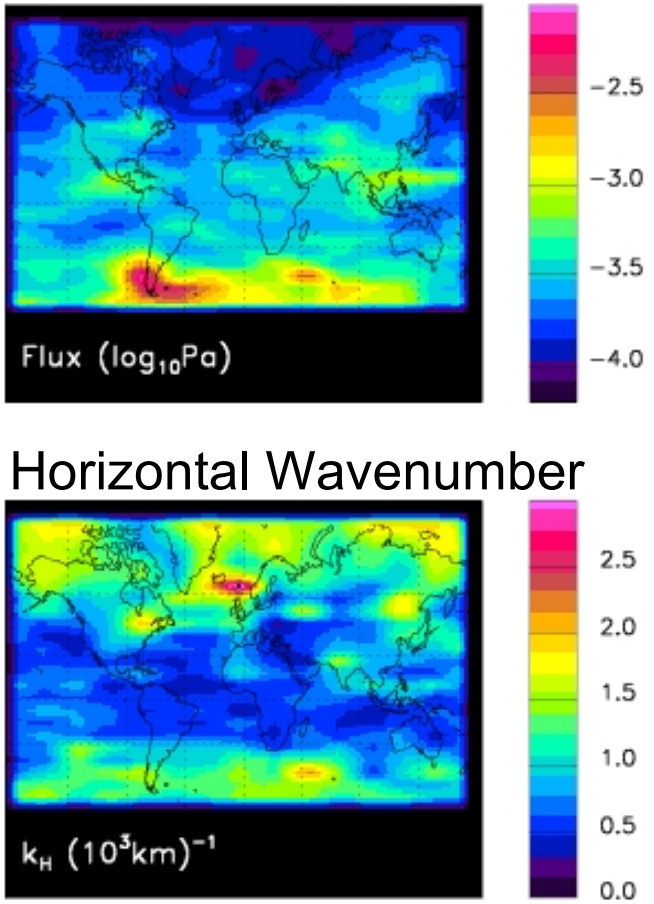
Alexander et al. [2007]

Single Day 16 May

Temperature Amplitude



Momentum Flux

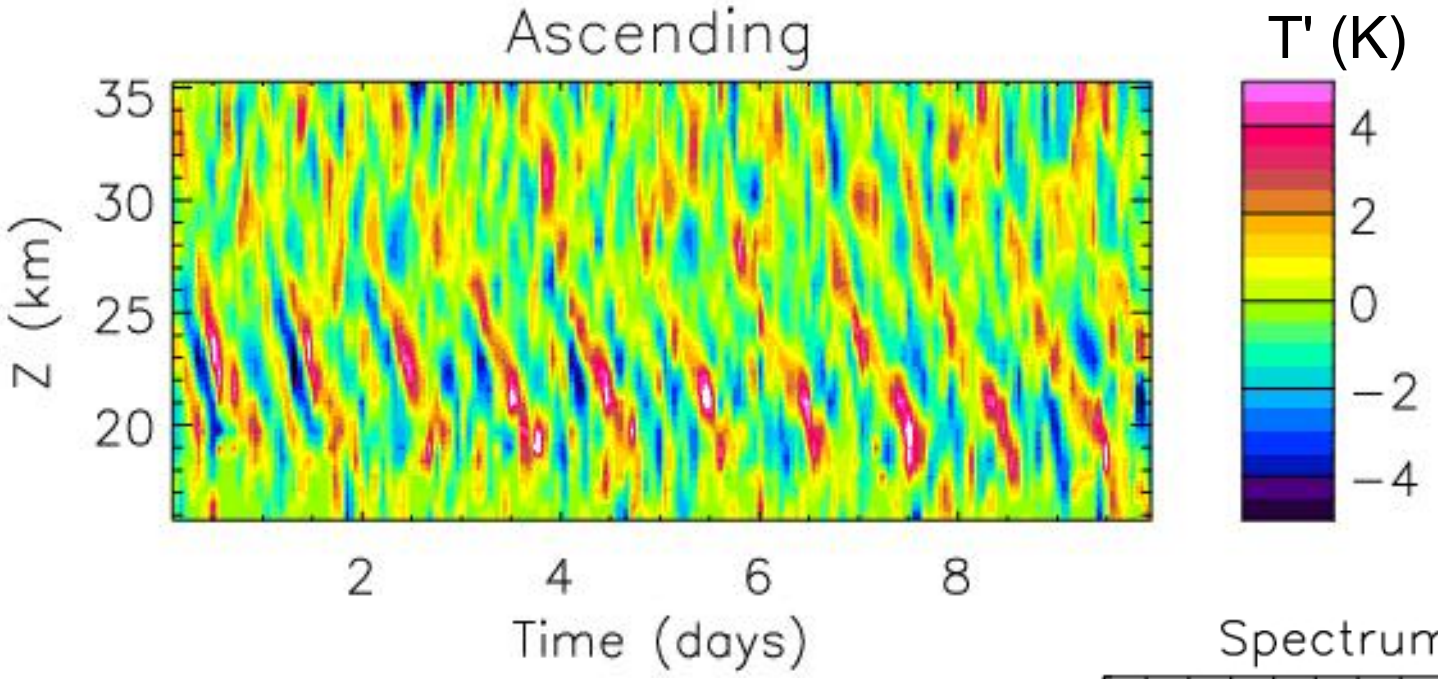


Vertical Wavelength

Horizontal Wavenumber

- Single day shows large amplitude events over Patagonia and SE Asia
- The SE Asia event has a very long horizontal wavelength along the meridional sampling direction, and correspondingly diagnosed with much lower momentum flux than the Patagonia mountain waves.

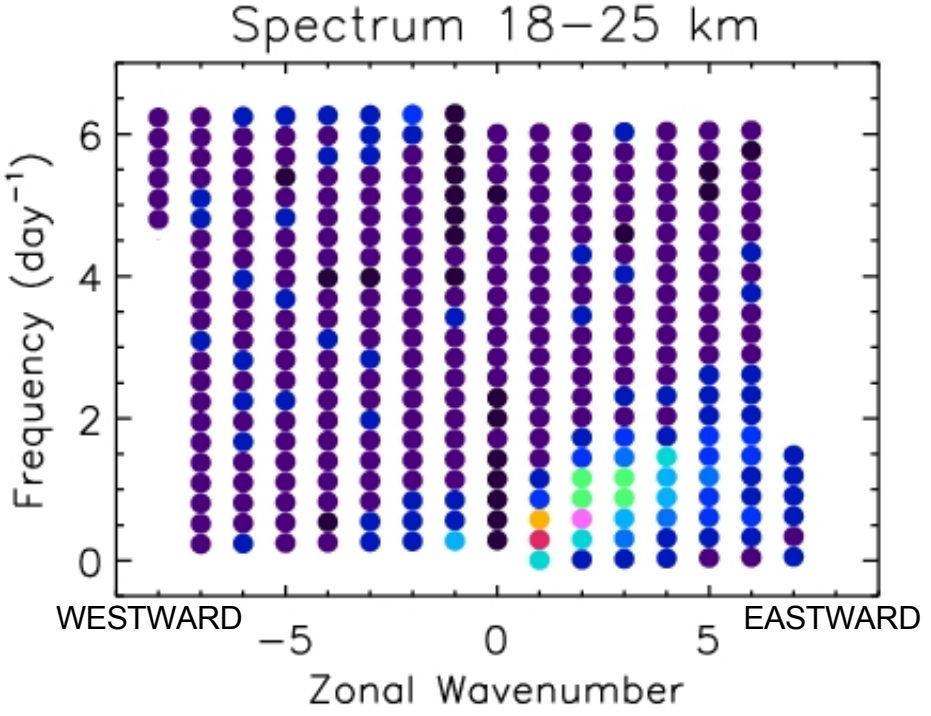
Equatorial Waves in HIRDLS



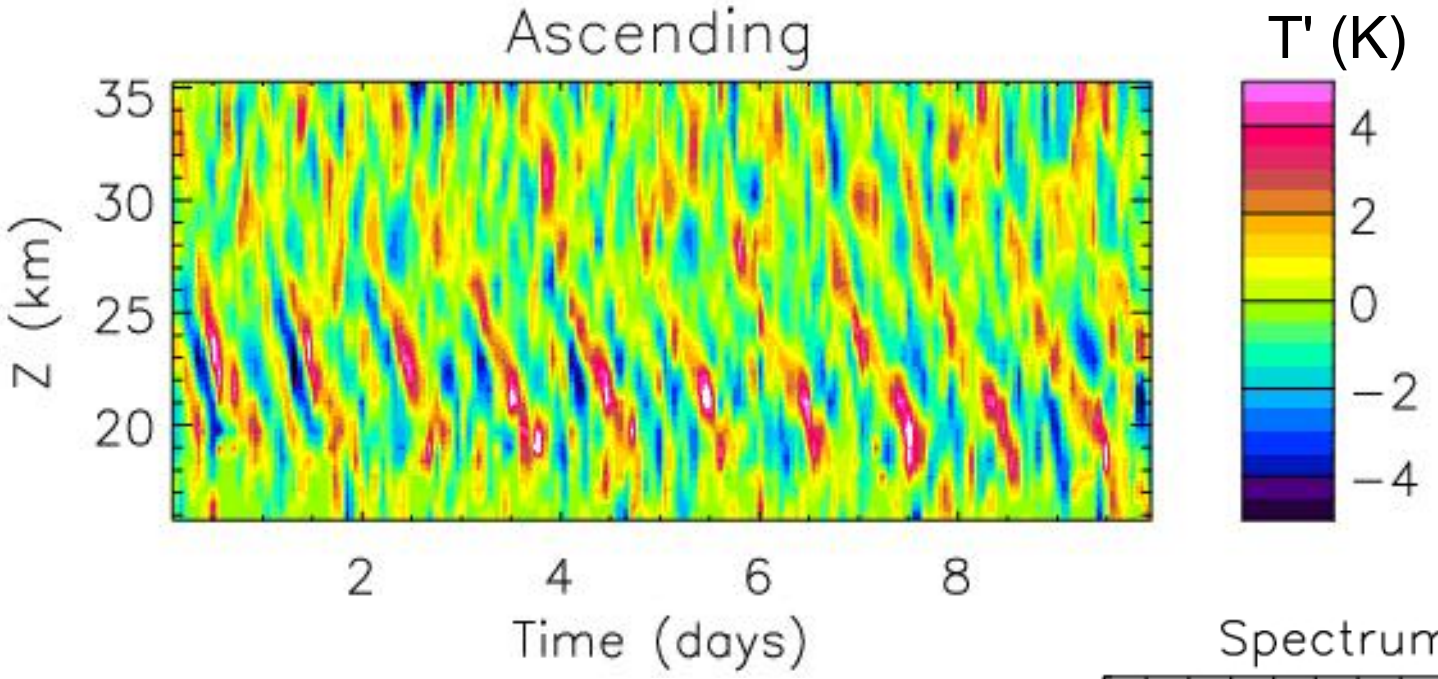
- 7-16 May 2006 at the Equator.
- Time / Longitude vary along X-axis.
- Eastward QBO phase.

Fourier Analysis of Asynoptically Sampled Data (Salby, 1982)

The resolved wavenumbers and frequencies (22-day sample) show a cluster of eastward propagating modes.



Equatorial Waves in HIRDLS



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Fourier Analysis of Asynoptically Sampled Data (Salby, 1982)

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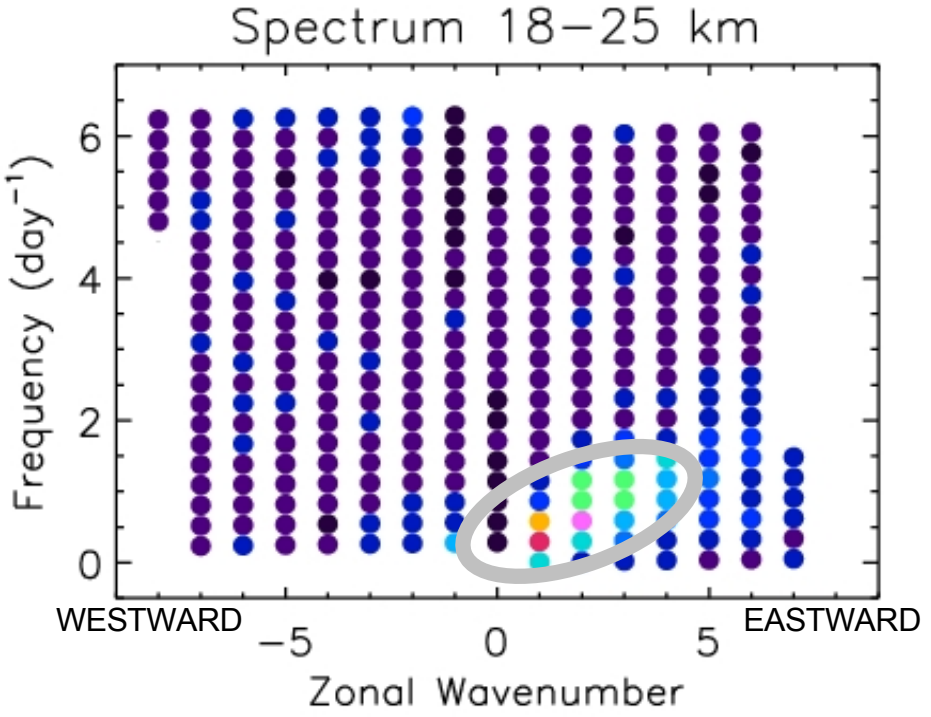
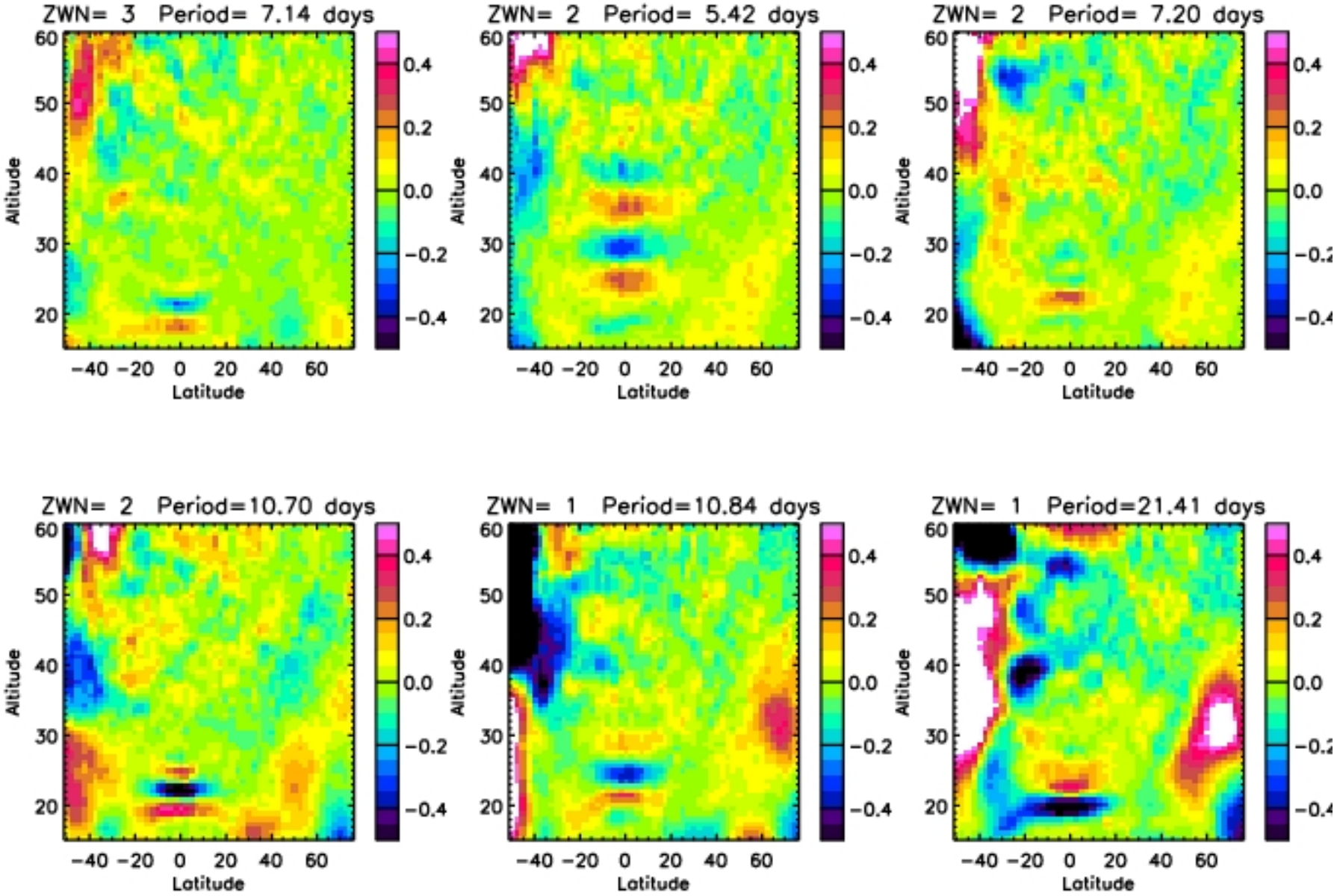
Zonal Wns = 1-3
Periods = 5-20 days



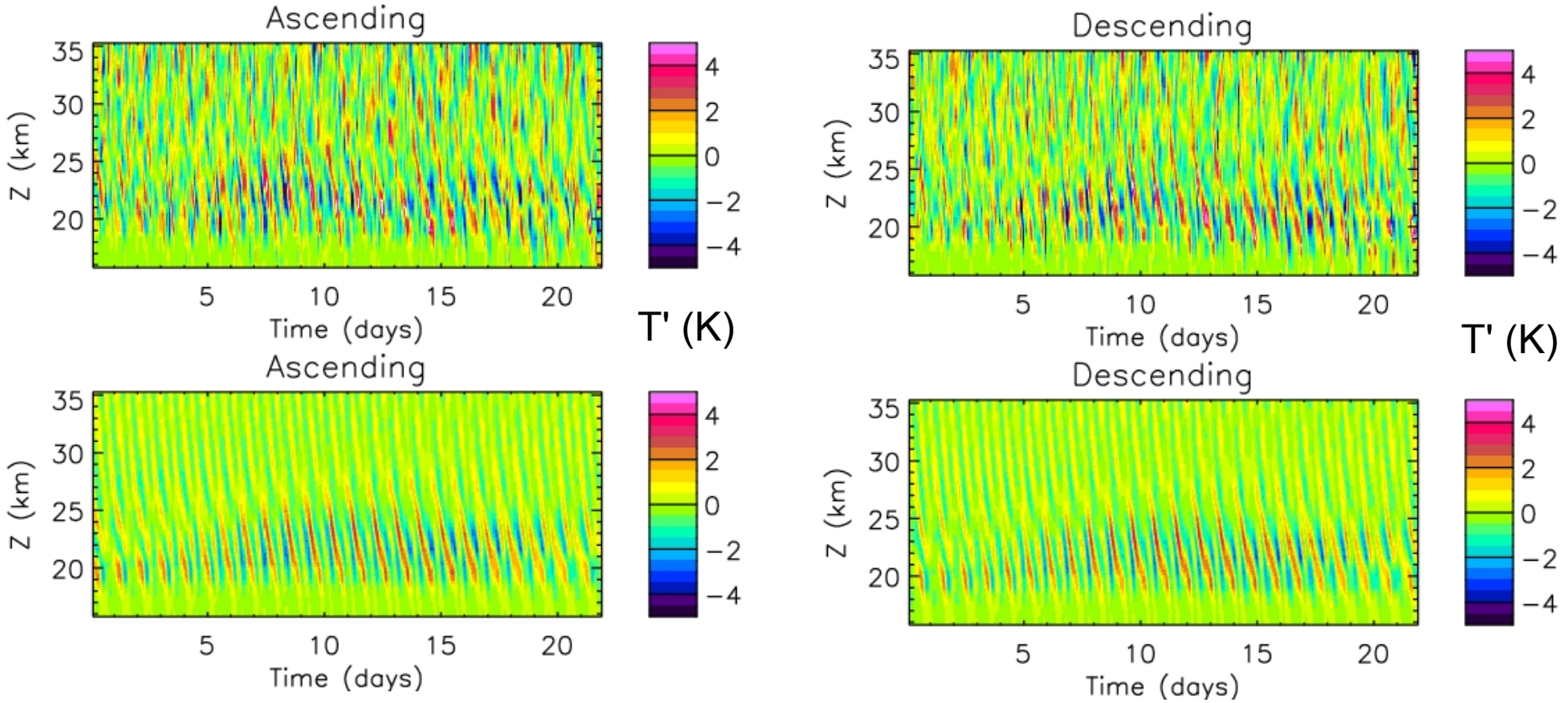
Equatorial Waves in HIRDLS

Latitude / Height Structure of Top 6 Modes Identified in the Fourier Analysis



Equatorial Waves in HIRDLS

Reconstructed Time / Height Series Compared to HIRDLS Data

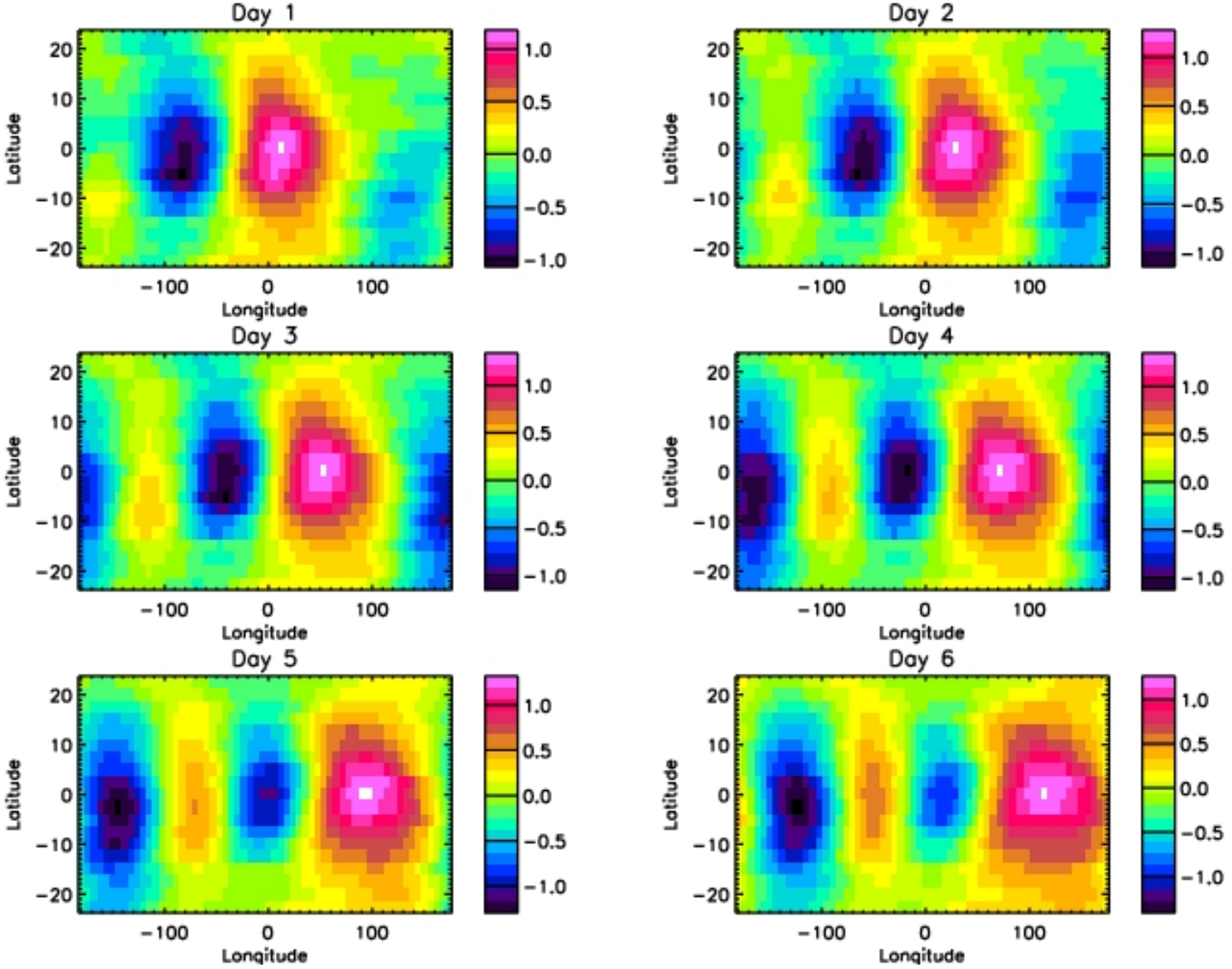


Sum of 7 modes with amplitude > 0.2 K [wavenumber, period(days)]:

[1, 10.8], [1, 21.4], [2, 5.4], [2, 7.2], [2,10.7], [3, 5.4], [3, 7.1]

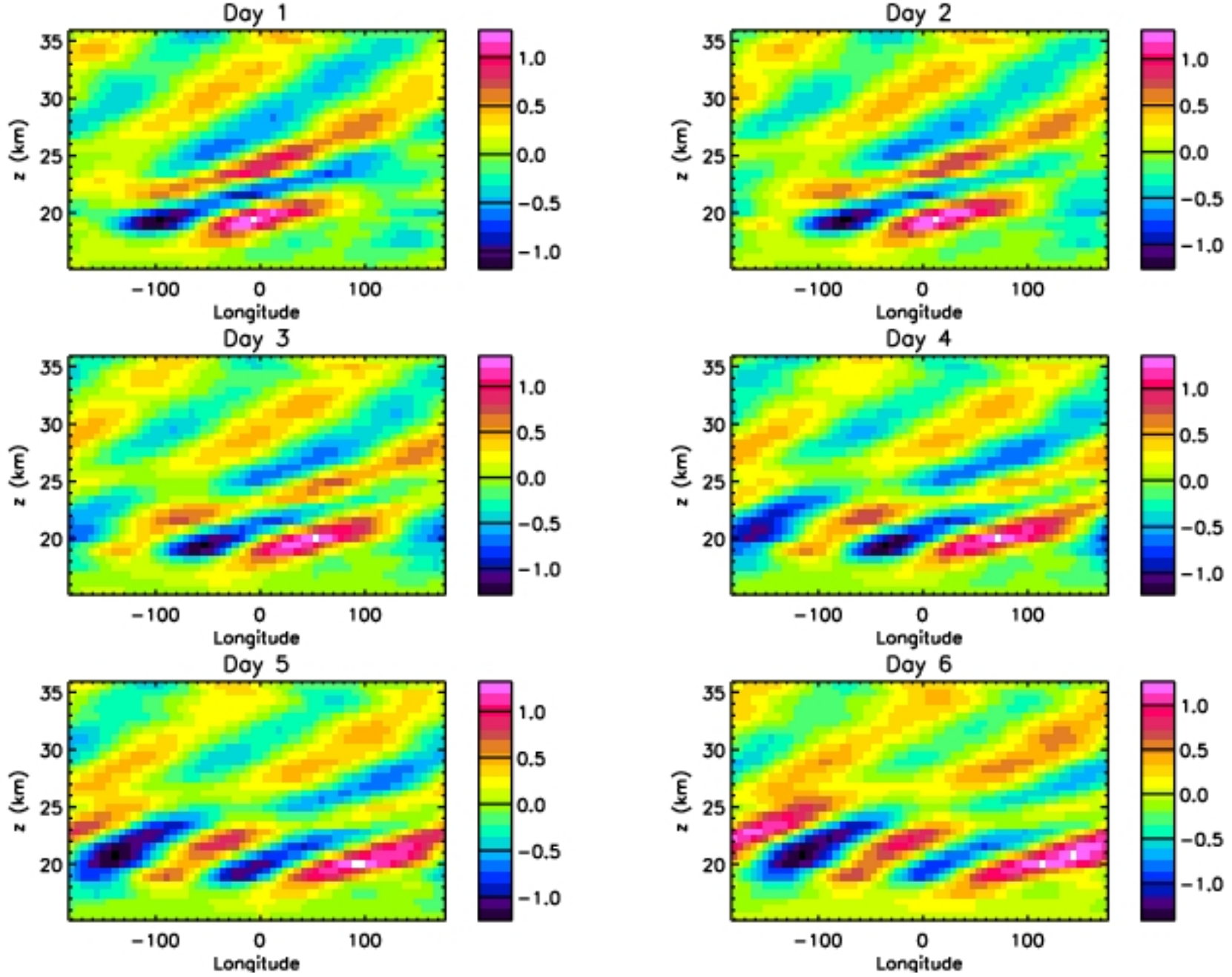
Equatorial Waves in HIRDLS

Reconstructed Longitude/Latitude Time Series



Equatorial Waves in HIRDLS

Reconstructed Longitude/Height Time Series



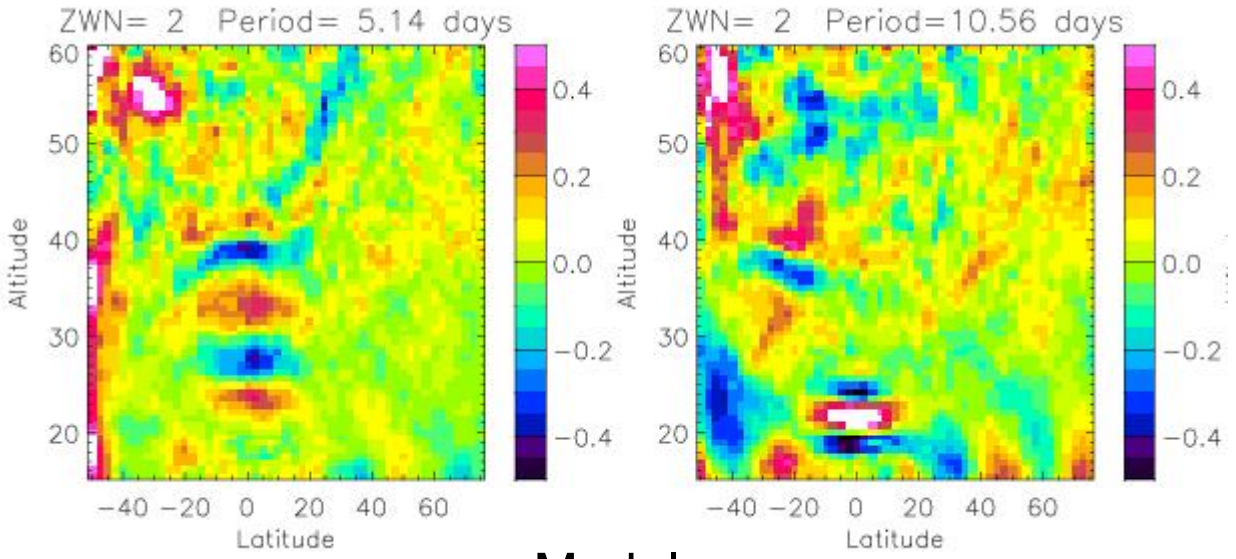
Equatorial Waves in HIRDLS

Idealized T80 Model Comparisons

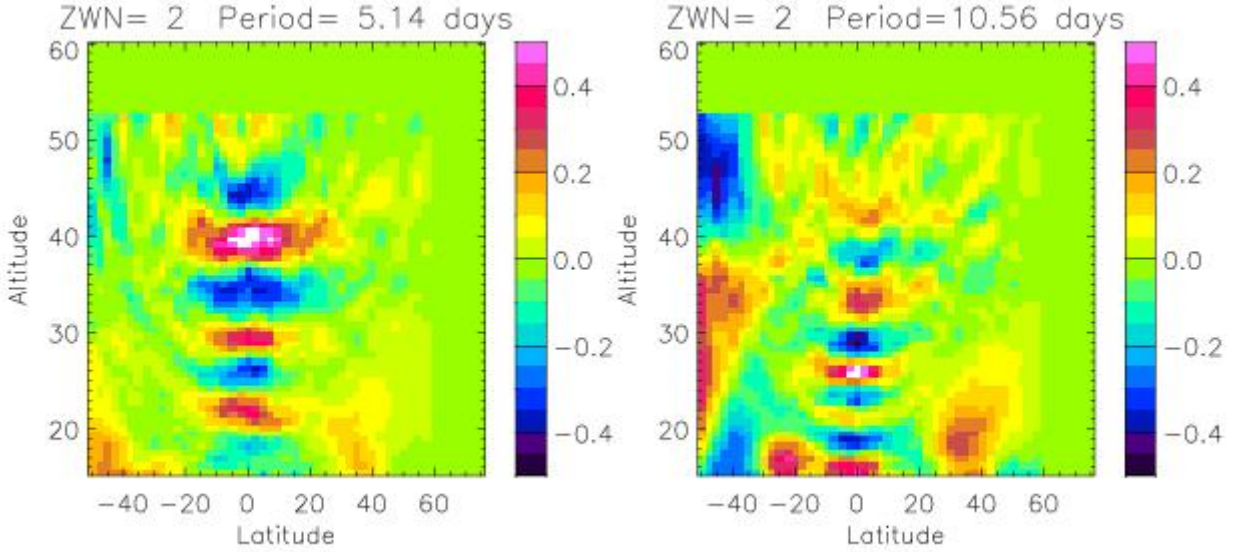
Meridional Cross-Sections
for Wavenumber=2 modes

- Model forced by 0.25°x0.25° 3-hrly heating derived from TRMM 3B42 rainfall rate product and geostationary IR cloud-top temperatures.
- The model reproduces the observed large scale waves.
- The model further resolves a broad spectrum of waves including gravity waves.

HIRDLS



Model

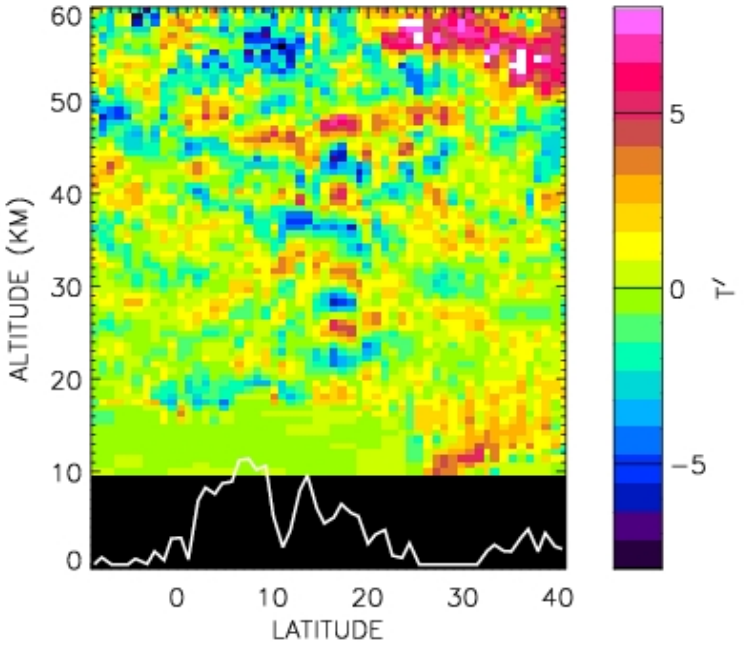


Equatorial Waves in HIRDLS

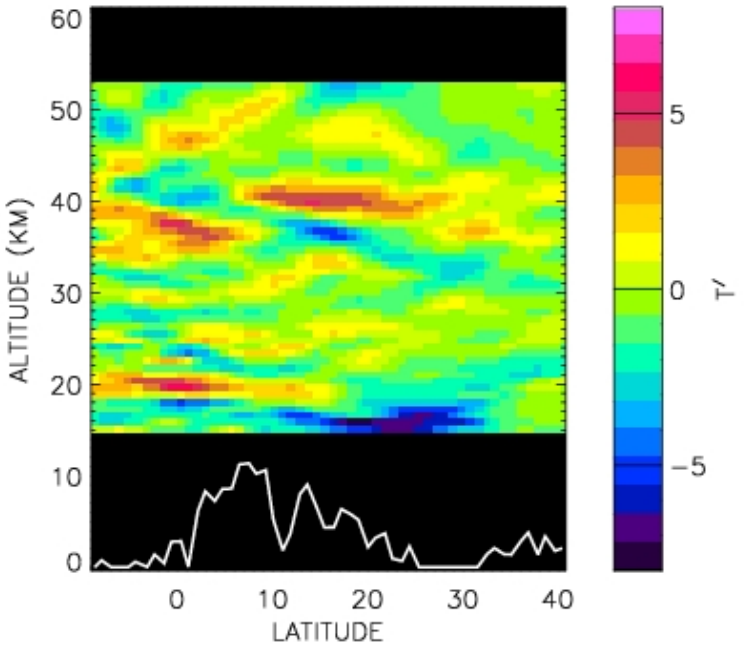
Single Day 16 May Cross-Section Thru SE Asia Event

HIRDLS Compared to Idealized T80 Model of Waves Generated by Convection

HIRDLS



T80 Model



- The HIRDLS “SE Asia gravity wave event” appeared in only two orbits.
- Showed no clear phase variations with latitude in the cross-sections.
- The model contains a very similar wave structure analyzed as a zonally propagating wave with wn~10 not resolved in the HIRDLS Fourier analysis.
- The HIRDLS gravity wave momentum flux assumed meridional propagation, and underestimates the flux for this zonal wave by a factor > 2.

Summary

- HIRDLS temperature profiles quantify the properties of atmospheric waves above cloud tops.

- Global analysis of gravity waves in HIRDLS shows latitudinal trends:
  - Large amplitude waves in the tropics and winter high latitudes
  - Highest momentum fluxes in winter over topography
  - Trend of decreasing horizontal wavelength with latitude

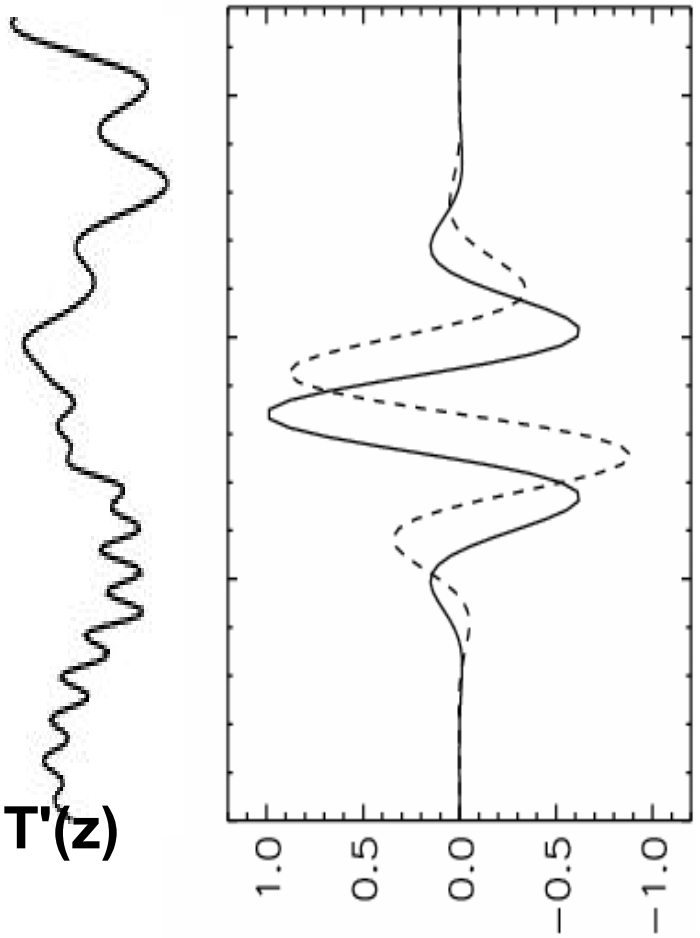
- Near the equator our analysis assigns zonal gravity waves horizontal wavelengths that are too long and momentum fluxes that are too small.

- Idealized global model of waves generated by convection captures some of the key features of waves in HIRDLS.
  - With additional validation, may be used to extend the interpretation to higher wavenumbers and frequencies.

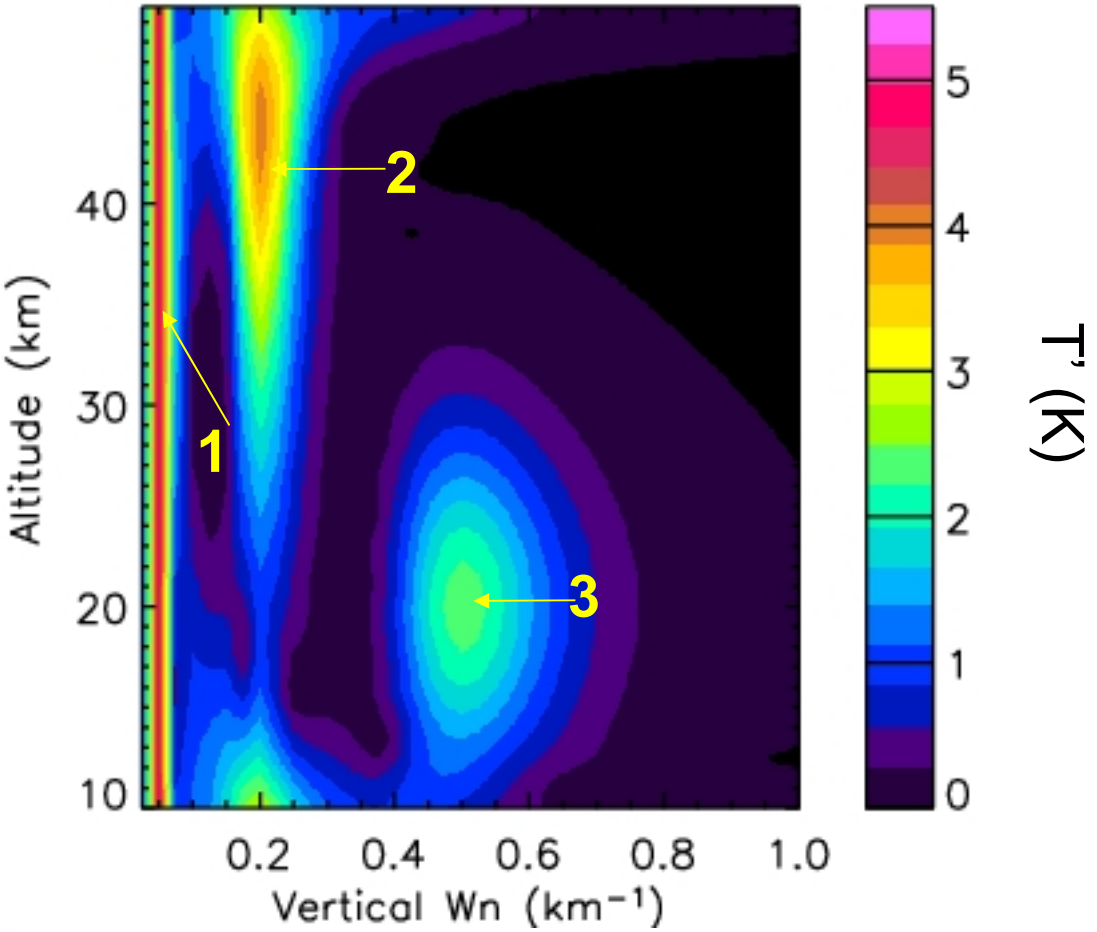
Along-Track: Wavelet Analysis

S-transform analysis of a synthetic vertical temperature profile

Example S-transform wavelet basis functions



Wavelet transform amplitude spectrum of theoretical 3-wave T' profile



Wavelet Analysis of profile series

Phase difference $\Delta\phi$ between adjacent profiles gives:

Horizontal wn = k ~ $\Delta\phi/\Delta x$